

United States
Department of
Agriculture
Forest Service
**Technology
&
Development
Program**
5100 Fire
Fall/Winter
1993
9451-2802-
MTDC



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The National Wildfire Coordinating Group (NWCG) coordinates wildland firefighting efforts among federal and state agencies. NWCG assigned the Missoula Technology & Development Center (MTDC) to coordinate the national effort and serve as the focal point for on-going and future studies on the effects of wildland fire smoke on firefighters. This status report, the seventh in a series, provides an update of project activities.

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Health Hazards of Smoke Fall/Winter 1993

Background

Concern for the health hazards of smoke is not new in the wildland fire community. MTDC evaluated the need for respiratory protection in the 1960's, and studied carbon monoxide exposure in the 1970's. In a 1985 Fire Equipment Working Team survey of over 2,000 fire management personnel, the need for respiratory protection from smoke did not emerge as a high priority. However, smoke and respiratory problems reported during the 1987 and 1988 fire seasons led to the development of a study plan to determine the immediate and long-term effects of exposure to forest fire smoke. NWCG assigned MTDC to coordinate the national effort. A technical panel was named to help establish research priorities.

Technical Panel Meets: The Health Hazards of Smoke technical panel met in Orlando in May, in conjunction with the NWCG Safety and Health Working Team. Panel members included Roger Ottmar and Tim Reinhardt from the Forest Service Pacific Northwest Research Station, Dave Blakely from the Intermountain Fire Sciences Laboratory, Claudia Finney and Dan Sullivan from the National Park Service, John Kelly representing the National Institute for Occupational Safety and Health, Lisa Choquette for California Professional Firefighters, Bill Weaver of the California Division of Forestry, and Dick Mangan and Brian Sharkey from MTDC. The agenda included a review of project activities and the development of priorities for FY94, 95, and 96.

Project activities were reviewed with the Safety and Health Working Team (SHWT) that over-see the project for NWCG. SHWT members include Dave Aldrich and Dick Mangan from the Forest Service, Stan Palmer for the Bureau of Land Management, John Watt for the California Division of Forestry, and Paul Broyles representing the National Park Service. The combined groups reviewed recommended activities and agreed on a list of priorities for presentation to NWCG. Top priority for FY94 will be to complete the employee exposure and emissions characterization studies to provide the data needed to conduct a comprehensive risk assessment and to focus risk management efforts.



Tara Rothwell conducts an arm endurance test in the University of Montana Human Performance Laboratory.

NFPA Standard

At the May meeting in Orlando, the National Fire Protection Association (NFPA) approved a new standard (NFPA#1977) *Protective Clothing and Equipment for Wildland Firefighting*. The standard includes a section in the appendix that deals with respiratory protection for firefighters. The appendix is not part of the requirements of the standard and is included for information purposes only. It includes options for respiratory protection including: a HEPA filter-equipped air-purifying respirator for filtration of respirable particles from the breathing air. The addition of sorbents to remove selected gases and vapors (e.g., cartridge with HEPA + OV/AG) could also be an option when greater exposure is anticipated, as in direct attack or on a prescribed fire. The appendix cautions that due to the potential for increased carbon monoxide exposure, the wildland firefighter's agency should provide programs to expand training and develop and implement procedures to monitor CO exposure when firefighters use air-purifying respirators. (For information on NFPA #1977 contact: NFPA, One Batterymarch Park, Quincy, MA 02269-9101).



Risk Assessment

The Health Hazards of Smoke project includes a series of research studies that will provide the data required for an integrated risk assessment. Risk assessment is described as an analytic approach used to organize large amounts of information from diverse disciplines to evaluate the possible impacts of exposure on human health. This synthesis of information from laboratory and field exposure studies, health effects, and other investigations will be the basis for the effective management of risk associated with wildland firefighting. However, since knowledge of exposure and health effects remains incomplete, and with uncertainties in various risk estimates, risk assessment will remain an inexact measure of the hazards associated with wildland firefighting.

The assumptions used in environmental risk assessment are based on the best available information from industrial experience, and from human and animal experimentation. Some are based on animal dose-response relationships, where high-dose animal exposures are extrapolated down to determine a dose that would be predicted to induce a very low level of effect in humans. Risk assessors and regulatory decision-makers generally follow

the precept "better safe than sorry," and err on the side of safety when faced with conflicting data and lack of scientific consensus. Furthermore, federal regulatory agencies interpret risks differently. For example, OSHA sets the time-weighted average (TWA) exposure limit for formaldehyde, an expected carcinogen, at 0.75 ppm, while NIOSH calls for a TWA of 0.016 ppm and a not-to-exceed ceiling of 0.1 ppm.

In a recent editorial, Thorne Auchter, past administrator of OSHA and current director of the Institute for Regulatory Policy, noted that risk assessments should meet the following criteria: They must be completely credible; they must allow one to distinguish risks that are substantial from those that are relatively insignificant; and they must describe risk in terms that the public can readily understand and appreciate. Auchter notes that the risk assessment approaches currently used by federal agencies usually do not meet these criteria, often incorporating invalidated assumptions, conservative safety factors, and non-consensus analytical techniques. They do not make clear that the risk depends on the degree of exposure, and they summarize results in misleading terminology. He calls for uniform principles to guide all federal risk assessments. The principles would require scientific objectivity, full disclosure of uncertainties or lack of consensus, explanation of the relationship between degree of exposure and risk, and description of risk in terms that are plain and concise. (Auchter, T.G., Risk Assessment Must Be Improved, Industrial Safety and Hygiene News, May, 1993).

Risk Assessment for the Health Hazards of Smoke project will begin when current studies of employee exposure and health effects are complete. Objectives include risk assessments for crew categories and firefighting tasks, including ignition, initial attack, line-holding, and mop-up on wild and prescribed fire. If possible, assessment will be made of the risks of acute, season-long, and chronic (multiple season) exposures. Attempts will be made to conform to the principles listed above as the risk assessment document is developed for field review.

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Health Hazards of Smoke Fall/Winter 1993

Research

Smoke Exposure Monitoring Update Reinhardt, T. Radian Corporation, Seattle, WA, 1993.

Smoke exposure among firefighters was measured at two Idaho wild-fires in 1992, the County Line Fire and the Foothills Fire ([Figure 1](#)). In the last issue of **Health Hazards of Smoke**, preliminary carbon monoxide exposure data were shown for a day at the County Line Fire. The results from this day were typical of inversion conditions, when smoke from a fire is prevented from dispersing by warm air overlaying colder air. In this case, the trapped pollutants declined as the inversion broke up in the late morning. [Table 1](#) presents preliminary exposure data for four other pollutants that a typical firefighter faced. Benzene, formaldehyde, acrolein, and carbon monoxide (CO) exposure concentrations are shown in parts per million (ppm). Respirable particulate is measured in milligrams per cubic meter. Figure 2 presents the total exposure data for the firefighter. Carbon monoxide concentrations have been scaled down by a factor of 100 to fit on the graph. The exposure over time for this firefighter shows a consistent trend among the five pollutants measured. This is encouraging for efforts to predict exposure to pollutants by monitoring surrogate compounds that are easy to measure (such as CO).



Figure 1—Firefighter wears sample collection system while holding fireline.

Table 1—Smoke Exposure Data at County Line Wildfire.

Start Time	Stop Time	Job Task	CO ppm	Resp Part (mg/m³)	Benzene ppm	Formaldehyde ppm	Acrolein ppm
0600	0630	Travel to site	0.0	0.00	0.000	0.000	0.000
0630	0640	Hike in	39.3	3.24	0.043	0.158	0.029
0640	0840	Hike in, dig line	39.3	3.24	0.043	0.158	0.029
0840	0900	Dig line	29.9	2.78	0.036	0.140	0.028
0900	1100	Dig line	20.5	2.32	0.029	0.122	0.028
1100	1206	Lunch	0.0	0.00	0.000	0.000	0.000
1206	1406	Dig line, mop-up	3.3	0.61	0.000	0.007	0.000
1406	2000	Mop-up, hike out	3.3	0.61	0.000	0.007	0.000

2000	2045	Travel to camp	0.0	0.00	0.000	0.000	0.000
Average for Firefighter #1			11.9	1.28	0.012	0.050	0.009

How significant are the exposures measured? The Occupational Safety and Health Administration (OSHA) recommends exposure limits for each of the hazards measured. [Table 2](#) shows exposure limits recommended by OSHA for the measured pollutants. These limits were developed to protect workers who work year-long in a standard 40-hour week at relatively sedentary jobs. Such limits may not be adequate for firefighters who face multiple contaminants simultaneously, over extended workshifts as shown in [Figure 2](#). In the last issue of **Health Hazards of Smoke**, we mentioned that NIOSH recommended that a biological model of carbon monoxide uptake and excretion might be used to define an altitude-adjusted carbon monoxide limit of about 20 ppm. Such models are not available for all the chemicals in smoke. A simple alternative approach produces the adjusted limits for the health hazards listed in Table 2. In this method, a reduction factor is calculated based on the number of hours worked in a day and the period of time between workshifts. The reduction calculation is as follows:

$$\text{Reduction factor} = 8/h \times (24-h)/16$$

Table 2—Exposure Limits.

	CO ppm	Resp Par (mg/m ³)	Benzene ppm	Formal ppm	Acrolein ppm
OSHA limits	35	5.0	1.0	0.75	0.100
Adjusted limits *	12.6	1.8	0.36	0.27	0.036
* See text for reduction factor					

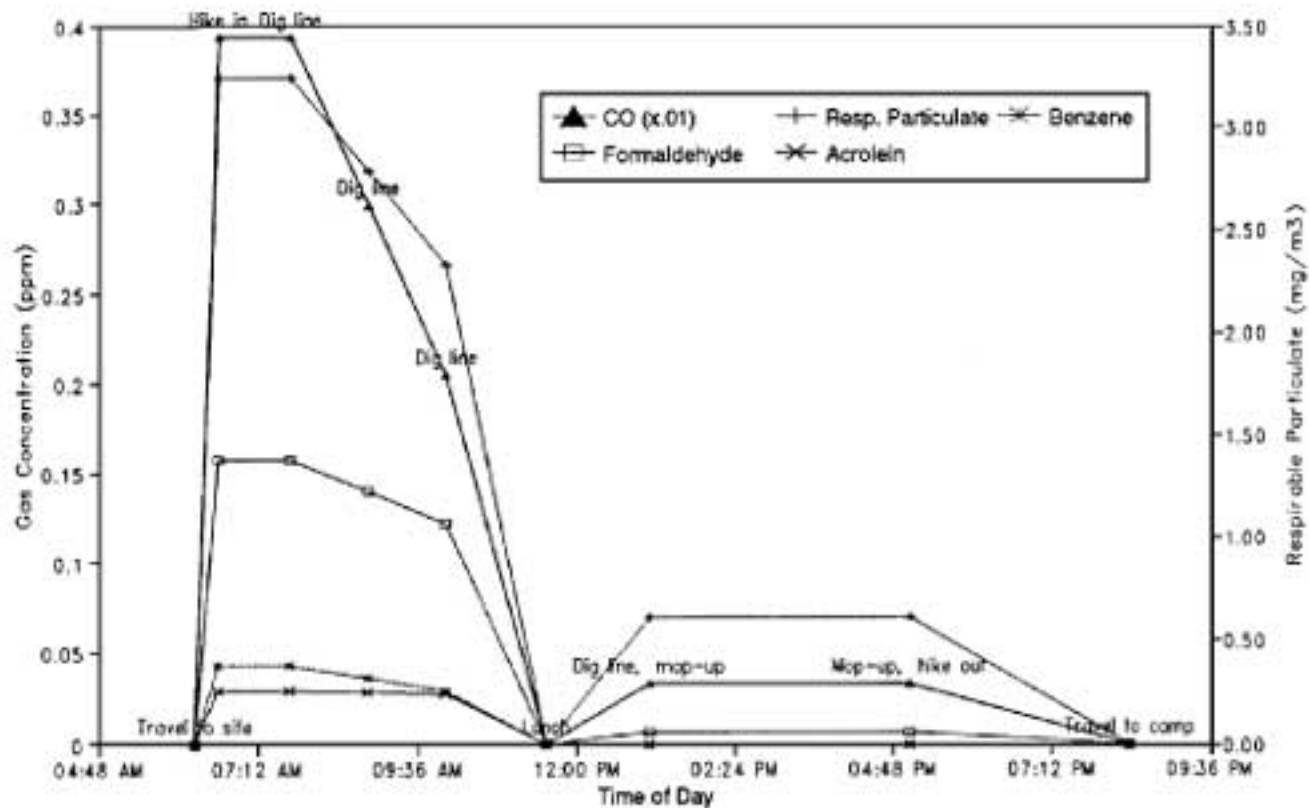


Figure 2—Smoke exposure at County Line Wildfire, (Firefighter #1, August 6, 1992).

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For the County Line firefighter example, a reduction factor of 0.36 is calculated for a 14-hour workshift. The OSHA exposure limits are multiplied by the reduction factor to produce the adjusted limits. This simple method shows the range that might be considered in defining what is an acceptable smoke exposure for wildland firefighters. Based on exposure to single chemicals, this simple approach probably overestimates the reduction factor necessary to adequately protect worker health. However, exposure to multiple compounds with similar toxic effects could indicate the need for even more stringent exposure limits. More work will be needed to reach consensus on a method for calculation of a reduction factor appropriate to the arduous but seasonal work of wildland firefighting.

The calm wildfire season has limited measurements of smoke exposure in 1993. However, smoke exposure among firefighters has been measured at many prescribed fires this year. Smoke exposure at prescribed fires can range between minor and unhealthy, depending primarily on wind conditions. A final report about prescribed fire smoke exposure will be available next spring.

Initial attack smoke exposures were monitored this year in chaparral ecosystems, on behalf of the California Department of Forestry and Fire Protection. [Figure 1](#) shows a firefighter wearing the smoke monitoring equipment. Early review of the initial attack data show that carbon monoxide concentrations were not found to be excessive, remaining below 45 ppm in 20-minute samples. The wildfires that produced these samples were typical of many small initial attack fires found in grass and chaparral, but not as intense as can be encountered. The California Department of Forestry and Fire Protection is considering steps to protect firefighters against smoke inhalation.

Note: *The Health Hazards of Smoke technical committee will continue to search for a method to calculate exposure limits appropriate to the multiple hazards, arduous work, extended shifts and seasonal nature of wildland firefighting.*

Predicting the Effect of an Air-Purifying Respirator on Sustained Work with the Arms Rothwell, T., DeLoreozo-Green, T., and Sharkey, B., Forest Service Technology & Development and University of Montana Human Performance Laboratory, Missoula, MT.

Air-purifying respirators (APR) have been shown to affect treadmill performance via breathing resistance, dead space, heat stress and weight. Studies of arm work have shown diminished levels of pulmonary ventilation that might exacerbate the effects of an APR. This study evaluated the effect of an APR on sustained arm work and attempted to predict the ability to perform while wearing an APR. Nine male and nine female volunteers (ages 20-36) performed pulmonary function tests, leg tests of maximal oxygen intake, arm tests of peak VO_2 w @ w/o the APR, muscular fitness tests, sustained arm work tests w @ w/o APR, and a field test. Blood lactate measures were recorded after each test ([Figure 3](#)). The sustained arm work test, with and without an APR (half-face APR with HEPA + OV/AG cartridges; airflow resistance = 36 mm H₂O @ 42.5 L/min), involved arm cranking at 60 rpm with the resistance adjusted to elicit a heart rate of 150 bpm. The field (pack) test consisted of a 4.83 km (3 mile) hike over level terrain while wearing a 20.5 kg (45 lb) pack. Results showed that the APR significantly reduced arm peak VO_2 (-2.24 ml/kg-min or 7.3%; $P < .05$) and arm peak Ve (-19.7 L/min or 18.3%; $P < .001$), but did not significantly reduce sustained arm work, in spite of a -3.15 watt or 5.5% difference ($P = .07$). Predictors ($P < .05$) of sustained arm performance with the APR for combined (male/female) data included: arm peak VO_2 w @ w/o APR (r 's = .597, .542), Arm VT (.654), Leg max VO_2 in L/min (.813), pulmonary function measures ($\text{FEV}_1 = .73$, $\text{FVC} = .729$, $\text{MVV} = .554$, $\text{PIF} = .560$, $\text{PEF} = .541$), bench press (.694), and Pack Test (-.708). Multiple regression analysis of sustained arm performance with an APR vs. FEV_1 and Pack Test yielded $R = .832$. Results indicate that arm work while wearing an APR can be predicted from pulmonary function and field performance measures.



Figure 3—Tara Rothwell collects (insert) and analyzes a blood sample for lactate following an arm endurance test.

Respirator Tolerance Harber, P., UCLA Occupational Medicine, Los Angeles, CA, 1992.

Respirators play a major role in protecting American workers from inhaled toxins. Proper understanding of their effects upon the user improves their design and the medical criteria for determining proper utilization. Unlike other workplace exposure controls, respiratory personal protection depends upon the volitional action of the worker in employing the device properly. This study focused not only on the adverse physiologic effects of the devices but also upon identification of those factors that affect the workers ability to tolerate the device, thereby directly affecting the likelihood of proper utilization. In addition to limitations of ventilation due to resistance to airflow, respirators have other effects including, subjective discomfort, changes in load sensitivity, changes in respiratory control pattern, and a switch from nasal to oral airflow. Furthermore, individuals differ in their sensitivity to inspiratory resistance, and this influences the subjective response to respirator use, and reduces the effectiveness of pulmonary function tests for selection purposes. For worker evaluation, the author

recommends measurements of actual respirator use in field settings as an alternative to carefully controlled laboratory tests. (NTIS #PB92-206085)

Respirator Performance Rating Tables for Mask Design Johnson, A.T., Battelle, Columbus, OH, 1990.

This report describes efforts to formulate physiological information in a way that can be used by respirator mask designers using computer-aided design (CAD) technology. Performance rating tables (PRT's) were developed for tasks at different rates of work in four environmental conditions. Findings indicate that the relationships of masks to their wearers are very complex, affecting sensory as well as physical interfaces. Performance degradation due to mask wear increases with task difficulty, heat, and humidity. At a medium work rate in a hot/dry environment, total performance degradation while wearing a military mask (M-17) is estimated at 63 percent compared to the no-mask performance. In operational terms, a 37 percent performance rating (63 percent degradation) means that a normal individual is expected to take 3 hours to accomplish with a mask what he or she did in 1 hour without the mask. Or to accomplish the task in the same amount of time, three workers are needed to do what one could do without the mask. Factors considered in the performance rating were respiratory, thermal, psychological, visual, communications, personal support (e.g., drinking/eating), and physical factors (e.g., compatibility). (NTIS #ADA-253-391)

Biologic Markers in Pulmonary Toxicology National Research Council, Wash., D.C., 1989.

Biological markers, which are indicators of biological exposure or change, offer the promise of early detection of the diseases caused by exposure to airborne environmental pollutants. This report is an in-depth look at the use of biological markers in detecting pulmonary disease. It includes a distinction among markers of exposure, markers of effect, and markers of susceptibility. Major issues explored include: usefulness of animal studies in developing markers for use in humans; the respiratory tract as a site for detecting pollution-specific markers; the role of respiratory function and other measurements in marker studies. (NTIS #PB92-238328)

Biologic Markers in Immunotoxicology National Research Council, Wash., D.C., 1992.

This report focuses on the human immune system and its response to environmental toxicants. It focuses on: how monitoring markers such as lymphocytes can be used to determine the effects of potentially harmful environmental toxicants; types of diseases resulting from immune suppression; hypersensitivity, auto immunity and immunodeficiency; and characteristics of the immune system. A section on exposure through inhalation discusses how three general categories of hypersensitivity (occupational asthma and rhinitis, hypersensitivity pneumonitis, and disorders associated with cellular immunity) can cause pulmonary disease. Another section discusses how inhaled pollutants can enhance susceptibility to or severity of viral, bacterial, and neoplastic diseases, and how this could be related to impaired immune function. (NTIS #PB92-238351)

Ineffectiveness of Cough for Enhancing Mucus Clearance in Asymptomatic Smokers Bennett, W., Chapman, W., and Gerrity, T., Chest, 102:412-416, 1992.

Authors studied the effectiveness of coughing for clearing mucous in 10 young (33 years) asymptomatic smokers. On three separate study days subjects inhaled 5 um particles under controlled breathing conditions. While seated in front of a gamma camera, retention of lung activity was measured during control and coughing. On the cough day, subjects performed 60 controlled coughs during the first hour of retention measurements. Results indicated that young smokers with normal pulmonary function were unable to enhance their rate of mucous clearance by coughing. The inability of these young smokers to enhance mucous clearance by coughing suggests a change in the mucociliary apparatus from normal (see related articles on pages 7 and 8).

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Health Hazards of Smoke Fall/Winter 1993

Risk Management

Pulmonary Function Screening

Studies of the respiratory effects of smoke exposure on wildland firefighters indicate that exposure during a fire season may result in small but statistically significant changes in lung function, as measured in a pulmonary function test. The health implications of short-term exposures and changes in lung function have not been quantified. While lung function data have been recorded in research studies, few subjects have been followed for several seasons to determine the effect of two or more seasons of exposure. Materna et al. (1992) recommended the use of lung function tests as part of an occupational health surveillance program for firefighters. MTDC is working with the Smoke Jumpers of the Missoula Aerial Fire Depot (AFD) to develop a pulmonary function surveillance program. AFD employees were chosen because the AFD houses a large number of firefighters who return for multiple seasons.

Prior to the 1993 fire season, 65 individuals completed a questionnaire that dealt with health, firefighting experience, and other exposures, and then were tested for pulmonary function. The computerized pulmonary function test provides measures of lung capacity, expiratory and inspiratory flow rates, and provides information concerning the health and capacity of the pulmonary system. Group and individual sessions to interpret test results and to discuss the health hazards of smoke followed the testing. Future plans call for annual pre-season testing to determine the long-term effects of exposure to forest fire smoke. Subsequent tests will be used to determine if firefighters are recovering between seasons or declining in pulmonary function at a rate that exceeds the decline of the general population.

In addition to providing a baseline for future comparisons, the lung function test provides information that could be used to identify individuals who are physically able to perform firefighting duties while wearing an air-purifying respirator (APR). Several measurements from the test (FEV1, PIFR) have been correlated with the ability to work while wearing a respirator. Measures of fitness (step test, treadmill test of VO2 max), which are highly correlated to lung function, also predict the ability to work while wearing a respirator. MTDC is working on a job-related field test that is correlated to pulmonary

function and fitness measures, and predicts the ability to work while wearing an APR. (For information contact Ken Heare, AFD (406-329-4965) or Brian Sharkey, MTDC (406-329-3989).

Respirable Particulate

An obvious nuisance as well as a potential health hazard in smoke are those pieces of airborne soot called particulate. The nuisance or hazard of particulate is dictated by the anatomy of the airways and the size and chemical composition of the particles. The upper reaches of the air-conducting system consists of large airways surrounded by cartilage and smooth muscle. As air continues down the system it moves into two main passages (bronchi) that divide sixteen times into ever-smaller branches, followed by respiratory bronchioles, alveolar ducts and, finally, alveolar sacs. Bronchial tubes are lined with mucous-secreting cells and hair-like cilia, but the terminal branches (respiratory bronchioles and alveolar ducts) are not ciliated.

Particles larger than 10 μm are removed in the nose and upper airways. Those between 3 and 10 μm are deposited in the upper airways, on the "mucociliary escalator" that sweeps debris upward for removal via expectoration or swallowing. Particles over 3 μm in diameter have little chance of avoiding the mucociliary escalator. Only those particles below 2 μm in diameter are likely to penetrate into the deeper portions of the lung, where deposition in alveolar sacs can occur via diffusion or gravity. Diffusion accounts for the deposition of the smallest particles in the distal portions of the pulmonary system. A large portion of the mass of particulate in forest fire smoke consists of particles less than 1 μm in diameter. What happens to particles that are deposited beyond the mucociliary escalator?

Particles deposited beyond the terminal bronchioles are subject to several mechanisms. Some are moved up to the mucociliary escalator on a slow moving layer of mucous. Many are ingested by macrophages, cells that process foreign material, and some of the macrophages move up to the mucociliary escalator for removal. Some particles remain on the surface of the alveolus. A fourth mechanism is movement of macrophages or particles across the alveolar membrane, where some remain in the interstitial space while others enter the lymph system for transport to the blood stream. The final mechanism is for particles to dissolve or disintegrate into smaller pieces. Whatever the fate of these particles, the self-cleaning ability of the lung is very efficient, and only a small fraction of inhaled particulate remains more or less permanently in lung tissue. Then why is respirable particulate a problem?

Particles can stimulate contraction of smooth muscle thereby narrowing the diameter of airways and raising the resistance to airflow. Deposition of particulate on the mucous membrane stimulates the flow of mucous, which also reduces the diameter of airways and the flow of air. These responses are reversible and not usually noticeable to most workers. But they can be pronounced in sensitive individuals who hyper-react to the presence of particulate, and may lead to chronic problems in a small number of workers. Some dust (e.g., free silica) prompts the formation of a fibrous cap over the inhaled particle, leading to pulmonary fibrosis and a potential reduction of lung capacity. Finally, the high turnover rate of surface cells in the respiratory tract makes them vulnerable to carcinogenic substances that can be transported via the particulate. Long-term exposure to these substances would increase the risk of metaplasia or malignant transformation of cells lining the airways.

In conclusion, the smoke from forest fires contains a high percentage of respirable particulate that has the potential to temporarily reduce pulmonary function. With adequate recovery time the healthy lung is capable of cleansing itself. Sensitive or hyperactive individuals are affected at lower concentrations, or experience greater reductions at higher concentrations. Prolonged exposure to the constituents of smoke reduces the effectiveness of some defense mechanisms (e.g., mucociliary escalator). Long-term exposure to high concentrations of respirable particulate-carrying carcinogenic substances (e.g., PAHs or polynuclear aromatic hydrocarbons) increases the risk of malignant transformation.

Note: *The Environmental Protection Agency (EPA) estimates that particulates cause between 50,000 and 60,000 deaths a year. Particulates are tiny bits of dust, soot and smoke that are emitted by burning diesel, wood, and other fuels, in industrial processes, and in plowing and burning agricultural fields. EPA has shown a correlation between increases in particulate pollution and mortality from asthma and other respiratory problems. Particulates cause nose and throat irritation, lung damage and bronchitis, and can lead to early death.*

Smoke and Heart Disease

The last edition of this report documented the effects of second hand or environmental tobacco smoke (ETS) on lung cancer and respiratory disorders. The EPA document did not deal with the effects of ETS on heart disease. Yet the public health burden may be even greater for heart disease than lung cancer according to a recent review of the epidemiological and experimental data. The *Journal of the American Medical Association* (1992) estimated that each year 35,000 to 40,000 excess heart disease deaths

among non-smokers are due to ETS. If second hand smoke from cigarettes can cause heart disease, lung cancer, and other respiratory disorders, what about the smoke from forest fires? Studies of breathing zone air samples collected on wildland firefighters and workers involved with prescribed burning indicate some potential for intermittent-seasonal exposure to the hazards of smoke. How this exposure compares with the daily, long-term assault of cigarettes or ETS has not yet been determined.

- *Smoking deadens ciliary action and interferes with the respiratory system's natural cleansing ability.*
- *Cigarette smoke suppresses the immune system and the defense against infection.*
- *The amount of carbon monoxide (carboxyhemoglobin or COHb) in the blood of smokers is 5 to 10 percent. OSHA's permissible exposure limits are designed to keep COHb below 5 percent, and studies on wildland firefighters indicate that exposures do not exceed the OSHA time-weighted average.*
- *Smokers get far more acrolein from cigarettes than firefighters breathe from vegetative smoke.*

A review of the extensive literature and informed scientific opinion from around the world has made it clear that tobacco smoking is the major factor in the causation of chronic obstructive pulmonary disease (COPD), including diminution of lung function. This is strongly reinforced by reports from the UK, the former USSR, Poland, USA, Africa, China, and Japan (Crofton, J. and Bjartveit, K. Smoking as risk factor for chronic airways disease, *Chest*, 96:3075, 1989).

The enormity of the health impact of smoking is all the more staggering in view of the evidence that over 40 percent of the deaths occur in persons under 65; many additional smoking-related deaths result from diseases other than lung cancer, heart disease, or lung disease (e.g., peptic ulcer); and millions more children and adults suffer health impairments because of exposure to smoke (Upton, A. On the costs of smoking, *Cancer Investigations*, 7:517, 1989).

As concern for worker health and safety grows, and as agencies invest in medical surveillance, monitoring, and risk management efforts including respiratory protection, it seems reasonable to eliminate the known health hazards of primary and secondary tobacco smoke. In addition to direct health effects (heart disease, lung cancer, respiratory problems) cigarette smoke increases the toxicity of other hazards (e.g., asbestos), deadens ciliary action, and suppresses the immune system, making smokers and those exposed to ETS less able to defend against other environmental assaults, including the health hazards in smoke. If cigarettes were invented

in 1993 the Food and Drug Administration would not allow them on the market. In the words of Dr. Paul Davis "To fight fire better, fight smoking too" (*Fire Chief*, February, 1993).

CDF Studies Respiratory Protection

In 1991, a decision was made by the California Department of Forestry and Fire Protection (CDF) to develop respiratory protection standards for its wildland fire suppression personnel. The decision was based on the rationale that CDF is primarily an initial attack oriented fire control organization, with an objective to extinguish 95 percent of all wildland fires at 10 acres or less. Achievement of this objective requires the maintenance of a highly mobile and poised fire control system that is capable of immediately responding to any wildland fire. Initial attack methods, involving direct fire suppression activities where firefighters perform arduous physical work at the fireline or in close parallel proximity (e.g., constructing hand-cut fireline, mobile attack with fire hose, extending hose lines) often results in firefighters being enveloped in thick, acrid smoke. This exposure forms the basis for the CDF respiratory protection project, which will define performance standards for the development of respiratory protection from the effects of short-term, acute exposures to wildland fire smoke.

The study will be conducted during the 1993 fire season. Training, medical certification, fit testing, and other necessary steps, will precede the field evaluation of respiratory protection devices and the smoke exposure data collection. The project will include both fire engine ground attack and helitack personnel and will emphasize evaluation during short-term, acute smoke exposure situations. Lawrence Livermore National Laboratory (LLNL) will analyze the data and compile a report for CDF.

CDF acknowledges that this short-term focus will not provide 100 percent protection from the health hazards of smoke, and is not oriented to the long-term exposures encountered on major wildland fires, where large geographic areas can be filled with smoke for extended periods. Long-term adverse health impacts from hours, days, and cumulative career exposures to smoke may have to be mitigated through other means, such as mandated safety practices, crew assignment rotations, or with opportunities for rest in smoke-free areas. For information on this project contact Bill Weaver, CDF Fire Research Coordinator (916) 653-5367).

New ANSI Standard

After several years of meetings, industry, government, and labor representatives have produced the latest edition of the American National Standards Institute (ANSI) voluntary guidelines on respiratory protection. This third version in the series, referred to as ANSI Z88.2-1992, is designed to help guide the practices of safety and health professionals and could influence future OSHA and NIOSH actions. The new standard has already had an influence on the Health Hazards of Smoke project. Members of the National Fire Protection Association (NFPA) sub-committee studying the need for respiratory protection for wildland firefighters were aware of the developing document and its call to use high efficiency particulate filters if a contaminant particle size was less than 2 microns. The Appendix of the NFPA standard Wildland Fire Service Protective Clothing and Equipment suggests the use of high efficiency particulate filters as an option for the filtration of respirable particles from the breathing air (forest fire smoke contains a high percentage of particles under 2 microns in diameter). Other features of the new ANSI standard include usage guidelines (e.g., a respirator is not to be worn if facial hair interferes with the face piece seal). For the first time, the standard permits contact lenses to be worn with respirators. (Copies of the Standard for Respiratory Protection are available from ANSI (212) 642-4900).

New ANSI Sub-Group

The Committee for Respiratory Protection of the American National Standards Institute (ANSI) is forming a new Z88 sub-group to develop performance standards for "filtering devices, providing respiratory and eye protection, to facilitate emergency escape from particulate matter, carbon monoxide and other toxic gases produced by fire." Certification and use of respiratory protection in an industrial setting is covered by NIOSH and other standards. However, respirators for non-industrial uses such as at home, in the office, in an aircraft, or in a hotel are not covered by any standard (except for some employees whose job is to respond to a fire). The sub-group began work in early November under the direction of interim chairman, Roger Killen. Brian Sharkey of MTDC has been invited to serve as a member of the sub-group.

Nutrition and Immunity

The last issue of this report outlined how a number of factors in the firefighting environment, including smoke, stress, fatigue and nutrition, are

able to influence immune function and the susceptibility to upper respiratory and other illnesses. Recent military training studies indicate that 300 additional calories per day will reduce the deleterious effects of arduous training on the immune system and performance of calorie deficient soldiers. And researchers are adding to the list of immune-friendly nutrients. To help maintain a healthy immune system, the well-balanced diet should include foods rich in the following:

Beta-carotene (from sweet potatoes, carrots) stimulates natural killer cells and serves as an anti-oxidant.

Vitamin C (from citrus fruits, broccoli, peppers) enhances the immune response and serves as an anti-oxidant.

Vitamin E (from whole grains, wheat germ, vegetable oil) stimulates immune response and serves as an anti-oxidant.

Vitamin B6 (from potatoes, nuts, spinach) promotes white cell proliferation.

Folate (from peas, salmon, romaine lettuce) increases activity of white cells.

Selenium (from tuna, eggs, whole grains) promotes action against toxic bacteria.

Zinc (from eggs, whole grains, oysters) promotes wound healing.

Fatigue, stress, and exposure to smoke combine to reduce the effectiveness of the immune system, and increase susceptibility to upper respiratory illness. By maintaining the intake of immune-friendly nutrients at optimal levels it should be possible to maintain a strong immune response.

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Health Hazards of Smoke Fall/Winter 1993

Coming Up

Technical Committee

The Health Hazards of Smoke technical committee will meet early in 1994 to review progress and set research priorities. The committee will work to identify a method to calculate exposure limits for the health hazards of wildland firefighting and will begin work on the risk assessment process that will be accomplished when the exposure, toxic substance, and health effects studies are completed.

Next Issue

The next issue of Health Hazards of Smoke will be available in the summer of 1994. If you have questions, a contribution to the report, or want to be added to the mailing list, contact Brian Sharkey c/o USDA Forest Service MTDC, 5785 Hwy 10 W., Missoula, MT 59808 (406-329-3989).

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